

State of the Art Blockchain Enabled Smart Contract Applications in the University

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Abstract

A comprehensive analysis is necessary for the implementation and use of smart contracts in companies. This overview clarifies how this technology is now being used and identifies problems that are preventing its usage in contemporary organizations. This paper offers an organized assessment of prior research that includes frameworks, techniques, functional prototypes, and simulations that show how smart contracts are used in businesses. This paper's main goal is to better understand how smart-contract technology is used in organizations today. While there is limited knowledge about how smart contracts are used in companies, there is significant progress being made in the development of the technology that supports them. In this work, we describe the characteristics of smart-contract applications in many current organization fields. We further examine and group issues that hinder the adoption of smart-contract applications.

Keywords: *Decentralized Autonomous Organization, Use Cases, Smart Contracts, Blockchain, Applications*

1. Introduction

Organizations now have to deal with issues including information security, stakeholder trust and openness, decentralization of operational procedures, and others [1]. Smart contracts and blockchain technology are developing, giving businesses new ways to tackle these issues. Smart contracts that use blockchain technology are computer programs that are constantly carried out by a network of nodes that have no trust in one another [2]. Without the need for a third party, smart contracts give businesses the ability to cooperate and carry out self-enforcing contract conditions in a blockchain network [3]. While researchers have been done on how smart contracts can be used to tackle various problems impacting contemporary businesses and while smart contracts offer new choices for organizations, little is known about how smart contracts are adopted in organizations [4].

By providing an overview of the commercial applications that support smart contracts, this article closes the gap [5]. This paper's main research question is: How can smart contracts be successfully implemented in contemporary organizations? The answer to this query enables the reader to comprehend the primary domain issues that smart contracts can address as well as the existing limitations of this technology [6]. From the main study topic, we infer the following sub-questions. In what areas do established firms use smart-contract applications? When making decisions about adopting smart contracts, enterprises find it helpful to have a grasp of the domains that use them. What are the primary advantages of

using smart contracts in these organizational domains? Definitions of a domain assist in concentrating on the key advantages that smart contract technology may provide for enterprises [7].

What problems prevent enterprises from using smart contracts to their full potential? Recognizing the restrictions enables the use of smart contracts in business operations to proceed without major issues [8]. The rest of the essay is organized as follows, Important background material is presented in Section I-A. The methodology employed in this study's literature review is described in Section II. The analysis of the findings is covered in Section III. Section IV discusses problems and offers recommendations for additional research. The conclusions of the overview are concluded in Section V, which also outlines the study's limitations [9].

A. Fundamentals of Smart Contracts

Blockchain technology enables smart contracts. Basic blockchain ideas like the Merkle hash tree, time stamping nodes and virtual machines, consensus, and the solidity programming language for creating smart contracts are all summarized in this section [10].

Programming Smart Contracts:

Programming languages that offer a way to execute computer code on blockchain nodes include Solidity. Smart contracts are computer programs that operate on a blockchain network and verify and enforce contracts digitally. Blockchain nodes are where smart contracts are executed and stored. Any user can run and execute smart contract functions from any network node that is a participant if they have the necessary access. Because Solidity is the programming language used by the biggest blockchain network that supports smart contracts, we concentrate on smart contracts written in Solidity for this study [11].

Blockchain:

The blockchain is a distributed ledger that lets users add and edit records, and encryption guarantees that the records are kept unchanged after being added. Transactions are used to add records to the ledger; these transactions are then hashed and organized into blocks. Each block is connected to the one after it cryptographically [12]. A cryptographic technique known as the Merkle tree or hash tree makes sure that transactions kept in a blockchain are connected using mathematical hashes. This ensures that no alteration will render the entire record invalid. The hashes offer a quick way to validate every blockchain transaction. By using this technique, records may be checked without having to search through all of the network's data [13].

Nodes and virtual machines:

Each participating node has a copy of the ledger, and the nodes that make up the blockchain network are connected as peers. The nodes are powered by virtual computers, such as the Ethereum Virtual Machine, which powers an Ethereum blockchain node (EVM). Each node updates its record by including the new block as soon as a new block is accepted by the network [14]. The participating nodes send transactions that are timestamped. The consensus technique for adding new records to the ledger is accepted by every node in the network. When a block is approved by the network, all of the participating nodes add the new block to their respective copies of the ledger. Transactions are organized into blocks [15].

2. Method of Literature Review

A systematic literature review methodology is employed in this study. A solid foundation for information systems research is provided by literature reviews, which also advance the discipline. The topic of blockchain inside information systems is strengthened by a survey of the literature on smart-contract applications [16]. The review is carried out in four

stages. Phase 1 involves reviewing the study's goals and protocol. Phase 2 entails literature research and practical screening. Phase 3 presents the quality assessment and data extraction. Phase 4 is where we analyze the results. This method of conducting a literature review was selected because it was created especially for information-system research [17].

Exclusion and Inclusion criteria:

Articles that are irrelevant to the study, articles for which a full paper cannot be downloaded or accessed, articles not published between 2013 and 2018, and articles unrelated to blockchain technology, distributed autonomous organizations or smart contracts are all excluded in the first stage of article selection [18]. High-quality white papers, journal articles, peer-reviewed conference papers, and articles on smart-contract applications in an organization are among the admission criteria for the second step.

The phase of execution: In the third stage of the review, we gather information from articles to be used as the basis for the analyses and extract data from those that are eligible based on the research questions driving this study [19].

Selection Phase:

In the second stage of the review, we use the Google Scholar database to look for academic articles [20]. We look for journal papers, conference papers, and a few white papers from 2013 to 2018 because smart contracts are a novel technology in information systems. We can use this time to help the search engine return relevant items. The following keywords and Boolean operators were used in our search for articles: To find papers with limitations and problems, the following keywords are used: problem + blockchain, problem + decentralized autonomous organization, and problem + smart contracts. Blockchain + business, blockchain + organization, blockchain + organization, distributed autonomous organization + business, and decentralized autonomous organization + organization. In every search, we use these pairs separately. We effectively screen the information we find from the search results, eliminating duplicates, articles that aren't pertinent to the study, and articles for which we can't access the full text. After this initial filtering, we received 469 papers in total. Figure 1 of the study shows this procedure [21].

Planning Phase:

We create a review protocol in the first stage since it is crucial to completing a systematic literature review investigation. A review methodology also reduces biases in a thorough strategy. We discuss the review's objectives before developing the protocol, a plan for searching, a set of selection criteria, a technique for extracting data, conducting data analysis, and presenting the findings [22].

3. Analysis of Result

In this section, we study the reviewed literature to learn more about the current applications of smart contracts in companies and the current barriers to their adoption. This is how the subsections are organized: An examination of smart-contract applications within the company is provided in Section III-A. The blockchain problems that enterprises face while adopting smart contracts are described in Section III-B [23].

a. Analysis of Blockchain Issues Mitigating Smart-Contract Adoption

We look at current problems and technical restrictions affecting blockchain technology. Our findings are based on the blockchain nodes' timestamping virtual machine, the cryptography used to secure digital signatures, the consensus method used to confirm transactions, and the Solidity programming language used to create smart contracts. We further investigate the impact of the identified problems on the organization's various smart

contract application domains. In this analysis, we only take into account the top application domains [24].

1.) *Results of blockchain analysis of limitations:*

We list 18 drawbacks of blockchain technology. We discovered that the technologies affected are the digital signature (55.6%), consensus (50%), Solidity programming language (38.9%), PoW consensus mechanism (27.8%), and nodes (27.8%) from the analysis as shown in Figure 2 in the paper. We examine the application domains that are impacted by the constraints mentioned. All of the application areas that we look into are impacted by the majority of the limitations (61.1%) that are listed. All applications that employ tokens are affected by the problems that are described by 72.2% of the constraints [25].

Apps on public blockchains are each offered by 72.2%, whereas 66.7% of respondents mention limitations that affect PoW-based applications. IoT, Smart Cities, and SCM domain restrictions are discussed in 66.7% of the literature, while 72.2% of the literature discusses limitations for applications in the finance domain. Figure 3 in the paper illustrates how smart contracts in both public and private networks are impacted by the present blockchain constraints. The graph demonstrates that there are distinct blockchain problems that exclusively affect public networks. The majority of restrictions, however, apply to both public and private blockchains. Only private blockchains are affected by no particular problem. Private blockchains, which often use voting-based consensus methods for approving transactions, are unaffected by the problem of an unsustainable consensus process given by PoW.

The trusted-party requirement problem is resolved since all participating nodes are known and trusted because of the control that permission blockchains have over the process of approving members. We also examine Table 2 to ascertain the severity of the current blockchain-related constraints. With this, we pinpoint crucial problems that should be addressed before smart contracts are used within the company. Low important, substantial, and critical severity levels provide the basis for categorizing this analysis. The study's Figure 4 depicts the severity of the existing problems affecting blockchain technologies. The concerns are arranged according to importance.

The triangle's bottom point is where the less major concerns are, its middle point is where the substantial issues are, and its top point is where the vital issues are. The report lists usability and complexity concerns, uniformity, a lack of testing and real-world experience, and design architecture issues as the key constraints of blockchain technologies. Scalability of storage, legislation, the soundness of smart contracts, security flaws and bugs, privacy leaks, smart contract lifecycle management, and untested consensus techniques are further key issues. Anonymity, scalability over time, transaction costs, cryptocurrency unpredictability, unsustainable consensus methods, trustworthy third-party involvement, and bitcoin liquidity difficulties are the less critical issues.

b. Analysis of Blockchain Issues Mitigating Smart-Contract Adoption

The year of publishing, type of publication, and subcategories to identify the smart contract's attributes are the categories on which we base our studies on smart-contract applications in the organizations. The type of publishing and the year of release reveals information about the caliber of the reviewed literature. We note the paper's publication date and whether it underwent peer review. We cannot disregard the significant contributions made by peer-reviewed literature on this subject, despite the overabundance of non-peer-reviewed papers in the form of white papers in the blockchain smart-contract community. We go on to examine the smart contract characteristics given in Table 1's property types. The organization, blockchain technology, type of network, application area, a problem that is intended to be solved, and contribution status are all identified as features of the smart contract. We specify the kind of organization for which the contribution was created in the organization characteristics of the smart contract. We further separate the organizations into public and private sectors. We specify the blockchain that the smart contract was intended to be

implemented on under technological property. We identify current blockchain technology that supports smart contracts using this property. We provide the kind of business transaction or process that the smart contract is intended to emulate in the application area.

The fundamental objective of using smart contracts in a specific application area is identified in the purpose category. This can be due to security concerns, privacy issues, trust-building efforts, etc. We specify whether the projects under analysis are theoretical descriptions, prototypes, or operational implementations in an organization in the state section.

1.) Results of the analysis of smart-contract applications are presented:

Table 1 provides an overview of the organization's analyses of smart-contract applications. We leave a project unmarked if it does not address the appropriate item or provide enough details on the classification. According to the table, 81% of the projects and studies examined have been published as peer-reviewed articles. 75% of all implemented projects have been published since 2017, and 59% of all projects have been published in that time. Because 87.5% of the projects examined were created for business organizations, these companies are the most popular ones for smart contract applications. Seventy-five percent of the projects that are put into action were created exclusively for commercial enterprises. 62.5% of the projects examined have either been prototyped or have been put into practice (working). Only 37.5% of the articles fall under the heading of theoretical descriptions and suggested frameworks/methods. Supply chain management (SCM), finance, healthcare, information security, smart city, and IoT solutions make up 71.87% of the application area/domain of the smart-contract projects that were examined. As a result, we list the top organizational domains for smart-contract applications.

Additionally, 75% of the projects that have already been put into action are in the fields of finance, SCM, and healthcare. The chart also demonstrates that an organization may employ smart-contract apps for several reasons, with roughly 44% of the projects citing either transparency or trust as the application's major goal. Other important factors are resource management, tamper-proofing, data security/privacy, and interoperability. Since 50% of implemented projects are hosted on Ethereum and Hyperledger Fabric, these two platforms are the industry leaders in smart-contract applications. Since 66.67% of the projects examined were prototypes, the Ethereum network is the technology of choice for smart contract projects in the firm. Additionally, 50% of the prototypes are run on open blockchains. However, 75% of projects that have been completed use private networks.

4. Discussions

We go over the findings from the analysis we conducted in part III of this section. Tables 1 and 2 of the paper contain the analyses' findings. We describe the findings of the analysis demonstrating smart-contract applications in the organization in the first half of this section. This section's second portion talks about current blockchain technology problems that have an impact on how organizations use smart contracts.

a. Discussion of Limitations

We talk about current restrictions on blockchain technologies in this section. The second section of this article discusses recent research addressing significant barriers to smart contract implementation.

1.) Limitations of smart contracts and blockchain:

Who can join the network, who can carry out the consensus process, and who is in charge of maintaining the shared ledger are all issues that both public and private blockchain networks must deal with. Due to concerns with blockchain usability and complexity, smart contract applications are difficult to employ in businesses. Complexity and usability issues with blockchain networks are particularly problematic for novice users. Additionally, blockchain technology has flaws with architecture and design that are unacceptable for business

activities. Several programming languages, including Solidity, Cardano, Tezos, Neo, etc., enable smart contracts. The blockchain has hardcoded consensus processes that are rigid. Consensus processes in blockchain technology are subject to some restrictions. The use of smart contracts in business applications may be constrained by the cost associated with completing transactions on the blockchain to pay miners. Still, as voting-based consensus techniques are typically used in permissioned blockchains, this does not apply to private blockchain networks. The volatility of cryptocurrencies is another drawback of the blockchain consensus mechanism, which makes it challenging to make long-term financial decisions. Similar to the well-known PoW and PoS, some of the recently proposed consensus approaches lack testing and dependability. The blockchain's digital signature technique has a few drawbacks. These include problems with anonymity, privacy breaches during transactions, and the participation of reliable third parties. Because blockchain nodes' storage capacity is restricted, the use of smart-contract applications that produce a lot of data is constrained. Applications for smart contracts that process and store a lot of data are impacted by this. Similar to the well-known PoW and PoS, some of the recently proposed consensus approaches lack testing and dependability. The blockchain's digital signature technique has a few drawbacks. These include problems with anonymity, privacy breaches during transactions, and the participation of reliable third parties. Because blockchain nodes' storage capacity is restricted, the use of smart-contract applications that produce a lot of data is constrained. This has an impact on smart-contract applications that process and store a lot of data. Numerous design difficulties, including security holes and bugs, soundness, and lifecycle management, affect the Solidity programming language. The ecosystem is full of numerous unidentified attack vectors, and Solidity code vulnerabilities are another problem. Furthermore, Solidity lacks a formal foundation, making it impossible to verify smart contracts using an algorithmic tool before deployment. The regulation of the network is a significant issue that affects both public and private blockchains. The legal difficulties relating to tokens, taxes, and intellectual property in a blockchain network are not properly addressed by any legal framework.

2.) Present-day research initiatives that address crucial blockchain constraints include:

A few of the obstacles to the widespread use of smart contracts have already been resolved. For instance, the resource and time scalability problems of PoW are addressed by the PoS consensus method. In PoS, a consensus is reached by choosing one of the nodes at random, according to their stake in the network, to build the following block. The likelihood of selection is influenced by systemic wealth. Because of this, some well-known blockchain platforms, like Ethereum, are implementing PoS as a consensus technique for their blockchains. Since its debut, the well-known blockchain platform Qtum has had a PoS-consensus mechanism.

3.) Scalability, third-party involvement, and privacy leakage:

Our analysis demonstrates that the problem of storage scalability is a significant restriction of smart-contract applications. Large-scale data from smart-contract applications can be stored utilizing decentralized database storage systems connected to an existing blockchain network, according to a study. In these systems, voting processes and shared replications of the data that is stored can be used to create immutability and trust. The fundamental disadvantage of this approach is that the storage is outside of a blockchain network, making it unable to ensure the immutability characteristic that blockchain offers in these systems. Some smart contract applications demand information on the state or value of an asset from a third party when a third party is involved. IBM creates microcomputers to solve this problem. These tiny computers may be connected directly to an asset and give an update on asset 2 because they are so compact. The SCM industry can benefit greatly from this. To give information on the status of assets, the current configuration of smart-contract applications in the SCM domain requires an RFID chip or equivalent tool. Because a blockchain node is not directly providing the information, we classify this as third-party involvement. An asset can become a blockchain node by using the microcomputers that can be attached to it, giving status updates without the need for a middleman. The issue of

information confidentiality in blockchains is covered by another study. All network members may view network transactions thanks to the way that blockchains are designed. According to certain studies, this problem can be solved by using private blockchain networks. Even in permissioned networks, privacy leakage remains a problem in private blockchain networks even though participation can be controlled. Only specific employees inside an organization must have access to complete business procedures. Because there is presently no way to restrict who can access information on blockchain networks, privacy leakage remains a problem. However, research tackles this issue and suggests the HAWK cryptographic protocol, which ensures the confidentiality of data recorded in a public blockchain. This is accomplished by including an additional compiler to convert common smart contracts into a cryptographic protocol shared by blockchain users. Information exchanged between the parties to the contract is encrypted and decrypted using the public key of a dependable third-party node to maintain secrecy. A major flaw in this protocol is the usage of a trusted third party, which goes against the decentralization and transparency principles of a blockchain. The problem of additional fees for confirming transactions carried out using this protocol is also a concern.

4.) Testing, design, and usability problems:

Our study highlighted some testing problems, one of which is the dearth of suitable testing frameworks for blockchain apps. Applications for blockchain, a relatively new technology, have not yet undergone adequate testing and may eventually fail. There are no frameworks for fault injection available right now to test blockchain systems. The Byzantine errors reflected in blockchain applications are not covered by existing approaches. To test distributed systems based on blockchains, the study suggests a new generation of fault injection frameworks for deployment in production. The paper suggests introducing Byzantine failures into the architecture to test and verify permissioned blockchain systems. Because of the lack of real experience with such initiatives, blockchain implementations cannot be properly tested. As a result, businesses do not switch over fast to blockchain solutions for their business processes. Since blockchain technology is a recent development, blockchain ecosystems contain unknown attack vectors. There are security flaws in the programming language Solidity. A smart contract can take control of a sender's contract and remove money from it when used as a payout address. The use of certain platforms is constrained by rigid consensus techniques, making it impossible to execute all business requirements in such a setting. Organizations should be able to select the consensus technique that best suits their needs. The Hyperledger Fabric platform offers the option for smart contract developers to select the best consensus method for their projects before deploying with a blockchain to address this issue. The main drawback of the Hyperledger platform is that PoS and PoW, the two most common consensus methods, are not supported.

5.) Standardization, regulation, and smart contract lifecycle management:

The creation of blockchain standards and laws is still in its infancy. Since blockchain is a relatively new technology, it is yet too early to establish what restrictions are necessary. Regulation and standards have received little academic attention. However, guidelines are being developed to address the dangers and abuses. On the other hand, because passing legislation will affect the advancement of blockchain technology, it is crucial to prevent excessive regulation that stifles innovation. To provide interoperability between various blockchain implementations, greater consensus, security and resilience, privacy and trust, and resilience, it is now necessary to define blockchain standards. Even though this report names smart contract lifecycle management as one of the problems hindering the organization's adoption of smart contracts, extensive research has been done to address this problem. A strategy for managing web-based electronic contracts is suggested by the study. We nevertheless find the study to be valuable because smart contracts are a type of electronic contract that is used in a blockchain network, even though it focuses on electronic contracts that are run via web systems rather than blockchain systems. Therefore, smart contracts and other kinds of electronic contracts can both be managed using the same process. A six-step

management process for smart contracts is suggested by the study. It entails proposal, configuration, publication, negotiation, operation, and closure. As a result, the design of a particular contract or agreement only applies to a single business operation; if the operation's aim is met and all parties are content, the contract is closed and a new one is established. The main disadvantages of smart contracts are that once they are put on a blockchain, updates or changes cannot be made, hence they are ideal for business processes with rules that don't change frequently. To provide a suitable way for controlling the lifecycle of a smart contract, more research must be done. For dispersed applications, the study offers a structured lifecycle management methodology. The setup phase, description of the decentralized governance infrastructure (DGI), enactment phase, and termination phase are the four phases the paper outlines for administering smart contracts. The contract negotiation stage is described in the setup phase when the parties involved describe the services needed and settle on a proposal for the contract. The DGI displays the items needed to execute an electronic transaction in a contract proposal in hierarchical order. The contract's implementation and behavior monitoring are shown during the implementation phase. Finally, the termination phase outlines the procedures needed to terminate the contract. When there is a problem, the framework also offers compensation mechanisms and the option for transaction rollback.

6.) Blockchain cloud platforms:

Blockchain as a Solution (BaaS) is a brand-new cloud computing service made available to businesses for using blockchain networks to process their daily operations. Leading blockchain-cloud service providers to include IBM³, Microsoft⁴, and SAP⁵, while other cloud providers are incorporating pre-existing blockchain technologies into their service offerings⁶. As an illustration, Amazon recently included QTUM in its blockchain platform offers for its web service services. There are various suggestions about how to integrate blockchain cloud services. In the paper, a practical blockchain as a service concept is put out that offers a more lightweight implementation of top-level business logic suitable for BaaS. The key benefit of this strategy is that it makes it simpler to create business logic for blockchain to enhance performance. Blockchain-based services still encounter some of the restrictions that are described in this study, even though BaaS makes it simpler for businesses to utilize blockchain for their business processes. The biggest drawback of blockchain-based cloud solutions is storage bloat. Additionally, the involvement of other parties undermines the fundamental tenets of blockchain.

b. Application discussion

The findings from Study III's Table 1 indicate that the majority are scholarly journals that have undergone peer review. This is an essential stage in evaluating the caliber of the initiatives that our study evaluates. Although the concept of smart contracts dates back to a manuscript written by Szabo Nick in 1994¹ and the Ethereum virtual machine was developed in 2014 to enable the possibility of running Turing complete programs on a blockchain, our research reveals that serious efforts to develop organization-blockchain applications only begin in 2017. This is clear from the fact that the majority of smart-contract implementation initiatives took place in 2017 or later. Blockchain enables the operation of trustless smart-contract applications for both public and private enterprises. According to the current survey, business organizations take the lead in the creation, adoption, and use of smart-contract projects. No particular smart-contract project created for military groups was found in our investigation. About 1200 results are found when you search "military blockchain applications" on Google Scholar. Our research, however, was unable to locate a real prototype or operational blockchain-based solution for a military organization. This may be related to the fact that most military applications are classified and not accessible to the general public. In our investigation, we identify the top organizational domains or application areas that include several smart-contract projects. We highlight SCM, banking, healthcare, information security, smart cities, and IoT solutions as the top application areas for smart contracts. Due to the

involvement of numerous cooperating stakeholders in their operations, these organizational domains share some characteristics. When it comes to SCM, for instance, parties like a supplier, buyer, transporter, etc. do not trust one another. Therefore, smart contracts that are enabled by blockchain are particularly relevant in these fields since they offer a transparent, trustless method for storing and carrying out transactions in an irreversible manner. Our survey also demonstrates that trust and transparency are the top motivations to embrace blockchains for all the projects we analyze, which serves as further evidence for this claim. Although there are other blockchains available for using smart contracts, our research reveals that Ethereum is still the preferred blockchain for developing smart-contract prototypes. However, projects are still being built using the Hyperledger Fabric and Ethereum blockchains. One of the blockchain technologies created by the open-source Hyperledger project is called Hyperledger Fabric. The Hyperledger project aims to create blockchain frameworks that work together across different companies. In addition to being a top service provider for businesses implementing blockchain technologies, IBM is a major contributor to the Hyperledger fabric project. Finally, our research demonstrates that permissioned networks are used to implement the majority of active projects. This is due to the privacy leakage blockchain vulnerability, which makes transactions visible to all network users. Although our study demonstrates that the privacy leakage problem impacts both private and public networks, it is less of a concern in private blockchains since permissioned networks can control who can join and participate in their network.

5. Conclusions

48 peer-reviewed papers that address the study subject of how to successfully implement smart contracts in contemporary businesses are analyzed in this paper. These papers are removed from the initial set of 496 search results. The chosen papers are then categorized by year, organization type, blockchain technology, network type, application area, problem to be solved, and contribution status. Finally, we look at current problems and any affected blockchain technology's technological limitations. According to our data, 87.5% of the firms using smart-contract applications are private. 75 percent of currently active initiatives are made particularly for private businesses. The majority of the initiatives under study (62.5%) have either been prototyped or are in use. Only 37.5% of the data are covered by theoretical explanations and suggested frameworks/methods. Supply chain management (SCM), finance, healthcare, information security, smart city, and Internet of Things solutions are the top industries where enterprises are using smart-contract applications (71.87%). Most of the implemented projects (75%) are in the healthcare, supply chain management, and financial sectors. We examine the motivations behind adopting smart contracts after evaluating the organizations that are doing so. Our analysis shows that the key advantages of using 44% of smart contracts in enterprises are transparency and trust. Other advantages include tamper-proofness, resource management, data security and privacy, and interoperability. We list 18 drawbacks of blockchain technology. Digital signatures (55.6%), consensus (50%), Solidity programming language (38.9%), PoW consensus mechanism (27.8%), and nodes (27.8%) are the technologies that are impacted. All of the application areas under investigation were affected by the majority of the limitations (61.1%). The problems that are common to all token-using applications are described by 72.2% of the constraints. Apps using PoW are affected by 66.7% of the constraints, whereas applications on public blockchains are each presented by 72.2%. 72.2% of applications in the financial domain have limits, and 66.7% of applications in the IoT, smart city, and SCM domains have limitations. The extent of the projects that were evaluated and the poor categorization of decentralized apps to take viable projects into account are some of the limitations of our study. While there are other smart-contract experiments underway in businesses that have not been included in any academic papers, our study exclusively takes into account programs that have been

published in scholarly journals. We suggest a study to assess the viability and usefulness of deployed decentralized applications in the blockchain ecosystem as future work.

References

- [1] S. Watini, Q. Aini, A. Khoirunisa, and U. Rahardja, "Assessment System for Testing the Evaluation of Diversity in Traditional Malay Dance by Early Childhood Students," *Int. J. Psychosoc. Rehabil.*, vol. 24, no. 8, pp. 2721–2729, 2020, doi: 10.37200/IJPR/V24I8/PR280291.
- [2] F. Agustin, F. P. Oganda, N. Lutfiani, and E. P. Harahap, "Manajemen Pembelajaran Daring Menggunakan Education Smart Courses," *Technomedia J.*, vol. 5, no. 1, pp. 40–53, 2020.
- [3] M. Saraswati, N. Lutfiani, and T. Ramadhan, "Kolaborasi Integrasi Inkubator Bersama Perguruan Tinggi Sebagai Bentuk Pengabdian Terhadap Masyarakat Dalam Perkembangan Iptek," *ADI Pengabd. Kpd. Masy.*, vol. 1, no. 2, pp. 23–31, 2021.
- [4] H. Purwanti, Z. F. Rahayu, W. Amelia, R. Dwi, and H. M. Bilqis, "Rancang Bangun Sistem Seleksi Rekrutmen Karyawan Dan Guru Berbasis Website Pada Sekolah Citra Bangsa Tangerang," *ADI Bisnis Digit. Interdisiplin J.*, vol. 1, no. 2, pp. 60–70, 2020.
- [5] S. Sutirna, "TOTAL QUALITY MANAGEMENT THROUGH LECTURER ASSESSMENT WITH STUDENTS TO IMPROVE GRADUATE QUALITY," *ADI J. Recent Innov.*, vol. 2, no. 1 Sept, pp. 227–242, 2020.
- [6] B. Mardisentosa, U. Rahardja, K. Zelina, F. P. Oganda, and M. Hardini, "Sustainable Learning Micro-Credential using Blockchain for Student Achievement Records," in *2021 Sixth International Conference on Informatics and Computing (ICIC)*, 2021, pp. 1–6.
- [7] N. Sari, W. A. Gunawan, P. K. Sari, I. Zikri, and A. Syahputra, "Analisis Algoritma Bubble Sort Secara Ascending Dan Descending Serta Implementasinya Dengan Menggunakan Bahasa Pemrograman Java," *ADI Bisnis Digit. Interdisiplin J.*, vol. 3, no. 1, pp. 16–23, 2022.
- [8] D. Rustiana, J. D. Pratama, T. Mudabbir, and M. A. Fahmi, "Adoption Computerized Certificate Transparency And Confidentiality," *Int. J. Cyber IT Serv. Manag.*, vol. 2, no. 1, pp. 1–10, 2022.
- [9] E. Retnaningtyas, E. Kartikawati, and D. Nilawati, "erma UPAYA PENINGKATAN PENGETAHUAN IBU HAMIL MELALUI EDUKASI MENGENAI KEBUTUHAN NUTRISI IBU HAMIL," *ADI Pengabd. Kpd. Masy.*, vol. 2, no. 2, pp. 19–24, 2022.
- [10] D. Rifai, S. Fitri, and I. N. Ramadhan, "Perkembangan Ekonomi Digital Mengenai Perilaku Pengguna Media Sosial Dalam Melakukan Transaksi," *ADI Bisnis Digit. Interdisiplin J.*, vol. 3, no. 1, pp. 49–52, 2022.
- [11] T. C. Husnadi, T. Marianti, and T. Ramadhan, "Determination of shareholders' welfare with financing quality as a moderating variable," *APTISI Trans. Manag.*, vol. 6, no. 2, pp. 191–208, 2022.
- [12] F. P. Oganda, "PEMANFAATAN SISTEM IJC (iLearning Journal Center) SEBAGAI MEDIA E-JOURNAL PADA PERGURUAN TINGGI DAN ASOSIASI," *CSRID (Computer Sci. Res. Its Dev. Journal)*, vol. 11, no. 1, pp. 23–33, 2020.
- [13] L. A. Faza, P. M. Agustini, S. Maesaroh, A. C. Purnomo, and E. A. Nabila, "Motives For Purchase of Skin Care Product Users (Phenomenology Study on Women in DKI Jakarta)," *ADI J. Recent Innov.*, vol. 3, no. 2, pp. 139–152, 2022.
- [14] U. Rahardja, "Meningkatkan Kualitas Sumber Daya Manusia Dengan Sistem Pengembangan Fundamental Agile," *ADI Bisnis Digit. Interdisiplin J.*, vol. 3, no. 1, pp. 63–68, 2022.
- [15] B. Rawat, N. Mehra, A. S. Bist, M. Yusup, and Y. P. A. Sanjaya, "Quantum Computing and AI: Impacts & Possibilities," *ADI J. Recent Innov.*, vol. 3, no. 2, pp. 202–207, 2022.
- [16] T. Ramadhan and R. D. Destiani, "Pengetahuan Manajemen Keuangan Bisnis Terhadap Niat Mahasiswa Bisnis Digital dalam Berwirausaha," *ADI Bisnis Digit. Interdisiplin J.*, vol. 3, no. 1, pp. 59–62, 2022.
- [17] M. Azmi, M. S. Shihab, D. Rustiana, and D. P. Lazirkha, "The Effect Of Advertising, Sales

-
- Promotion, And Brand Image On Repurchasing Intention (Study On Shopee Users),” *IAIC Trans. Sustain. Digit. Innov.*, vol. 3, no. 2, pp. 76–85, 2022.
- [18] P. A. Sunarya, F. Andriyani, Henderi, and U. Rahardja, “Algorithm automaticPrawira, M., Sukmana, H. T., Amrizal, V., & Rahardja, U. (2019). A Prototype of Android-Based Emergency Management Application. 2019 7th International Conference on Cyber and IT Service Management, CITSM 2019. <https://doi.org/10.1109/CI>,” *Int. J. Adv. Trends Comput. Sci. Eng.*, vol. 8, no. 1.5 Special Issue, pp. 387–391, 2019, doi: 10.30534/ijatcse/2019/6281.52019.
- [19] P. Hendriyati, F. Agustin, U. Rahardja, and T. Ramadhan, “Management Information Systems on Integrated Student and Lecturer Data,” *APTISI Trans. Manag.*, vol. 6, no. 1, pp. 1–9, 2022.
- [20] T. Nurhaeni, L. Nirmalasari, A. Faturahman, and S. Avionita, “Transformation Framework Design on Digital Copyright Entities Using Blockchain Technology,” *Blockchain Front. Technol.*, vol. 1, no. 01, pp. 35–43, 2021.
- [21] T. Ayuninggati, E. P. Harahap, and R. Junior, “Supply Chain Management, Certificate Management at the Transportation Layer Security in Charge of Security,” *Blockchain Front. Technol.*, vol. 1, no. 01, pp. 1–12, 2021.
- [22] P. Edastama, S. Purnama, R. Widayanti, L. Meria, and D. Rivelino, “The Potential Blockchain Technology in Higher Education Learning Innovations in Era 4.0,” *Blockchain Front. Technol.*, vol. 1, no. 01, pp. 104–113, 2021.
- [23] T. Ramadhan, Q. Aini, S. Santoso, A. Badrianto, and R. Supriati, “Analysis of the potential context of Blockchain on the usability of Gamification with Game-Based Learning,” *Int. J. Cyber IT Serv. Manag.*, vol. 1, no. 1, pp. 84–100, 2021.
- [24] A. G. Prawiyogi, A. S. Anwar, M. Yusup, N. Lutfiani, and T. Ramadhan, “Pengembangan Program Studi Bisnis digital bagi pengusaha dengan perangkat lunak lean,” *ADI Bisnis Digit. Interdisiplin J.*, vol. 2, no. 2, pp. 52–59, 2021.
- [25] Y. Durachman, A. S. Bein, E. P. Harahap, T. Ramadhan, and F. P. Oganda, “Technological and Islamic environments: Selection from Literature Review Resources,” *Int. J. Cyber IT Serv. Manag.*, vol. 1, no. 1, pp. 37–47, 2021.